Missouri Department of Natural Resources
Water Protection Program

Total Maximum Daily Load (TMDL)

for

Lamar Lake
Barton County, Missouri

Completed: June 29, 2006
Approved: July 20, 2006

Total Maximum Daily Load (TMDL)
For Lamar Lake
Pollutant: Nutrients

Name: Lamar Lake

Location: Near Lamar in Barton County, Missouri

Hydrologic Unit Code (HUC): 11070207-070001

Water Body Identification (WBID): 7356

Missouri Lake Class: L1[1]

Beneficial Uses[2]:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health associated with Fish Consumption
- Drinking Water Supply

Size of Impairment: 180 lake acres

Location of Impaired Lake: Dam in SW ¼, NW ¼, Section 32, T32N, R30W

Pollutant: Nutrients

Pollutant Source: Agricultural Nonpoint Source

TMDL Priority Ranking: Medium

1. Background and Water Quality Problems

Area History[3]:
Barton County has an area of about 600 square miles, four-fifths of which is elevated [former] prairie, sufficiently undulating for good drainage and not too broken for convenient cultivation. Running east and west through the county is the Ozark Divide, which sends water to the Missouri River on the north and the Arkansas River on the south. The dark, sandy loam is rich and productive. It is underlain by coal and large mines have been profitably worked in many places. Superior quality limestone and sandstone are produced in Barton County, the latter occurring in various shades of color. The sandstone has been used in many notable buildings, including the Barton County Courthouse, churches in Joplin and the Gulf Railway building in Springfield.

[1] Class L1 lakes are lakes used primarily for public drinking water supply. See Missouri's Water Quality Standards 10 CSR 20-7.031(1)(F)
[2] The beneficial uses may be found at 10 CSR20-7.031 (1)(C) and Table G
[3] Encyclopedia of the History of Missouri. Vol. I. 1901. Howard Conard, Ed. New York, Louisville and St. Louis. Halderman, Conard and Company, Proprietors

Barton County was created on December 12, 1855, and named for David Barton, one of the first two senators from Missouri. It was carved from Jasper County. A frame courthouse was built in 1858 to serve while a brick one was being constructed, which was completed in 1860. During the Civil War, however, this was burned to the ground. In 1868 another frame building was erected. Finally, in 1889, a spacious and handsome edifice was built, made of pressed brick and Barton County sandstone. A jail was not completed until 1871, with wrongdoers sent to neighboring counties in the interim. Real development in the county dates from establishing mineral interests, which followed the completion of the Kansas City, Pittsburg and Gulf Railroad in 1880.

The county was sparsely populated during the Civil War. No major battles were waged there, but many raids were made, with much pillaging and destruction of property and occasional murders.

Soils and Land Use:
Barco-Collinsville is the main soil association around the lake. It is shallow to moderately deep, contains gently to moderately steep soils in the uplands and is formed under grass in sandstone residuum. The soils are well drained. This soil association borders most of the larger streams and many upland drainageways in the county. It can be found in the broad and narrow bottoms of the North Fork of the Spring River and its tributaries. This is just one example of the kind and extent of the bottomlands included in this association. The predominant one is Hepler silt loam, a nearly level soil with moderate permeability and slow runoff. It is found on low stream terraces.

Barton County[4] is in the fruit belt and contains many fine orchards. It has a mild climate, so there is no need to shelter livestock in winter. In 1889, the prairie grasses were lush and they stayed green in the bottomlands through the winter, making it ideal for raising livestock. The watershed that feeds Lamar Lake is approximately 3,000 acres. Today, the land is 11 percent forest, 54 percent grassland, 23 percent cropland and seven percent urban. The remaining area is barren or open water. See Appendix A for the land use map.

Defining the Problem:
Lamar Lake serves as a drinking water supply source for the City of Lamar. It was created in 1955 by damming a small tributary to the North Fork of the Spring River, just southeast of Lamar. Tri-City Construction built the Lamar Lake Dam, which stands 26 feet high.

As already noted, the watershed of Lamar Lake is agricultural in nature. The agricultural fertilizer and animal manure used in farming are significant sources of nitrogen and phosphorus. High levels of these nutrients in the main stream feeding the lake have resulted in the production of large amounts of algae in the lake. Dieoff of large algal populations in the lake have led to chronic taste and odor problems. This is due to blue-green algae, which when they die, release specific compounds that cause unpleasant taste and odor.

[4] A History of Hickory, Polk, Cedar, Dade and Barton Counties, Missouri. 1889. Chicago. The Goodspeed Publishing Company.

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Targets

Beneficial Uses:
The beneficial uses of Lamar Lake, WBID 7356, are:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health associated with Fish Consumption
- Drinking Water Supply

The use that is impaired:
- Drinking Water Supply

Anti-degradation Policy:
Missouri's Water Quality Standards include the Environmental Protection Agency's (EPA) "three-tiered" approach to anti-degradation, which may be found at 10 CSR 20-7.031(2).

Tier 1 – Protects existing uses and provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 29, 1975, the date of EPA's first Water Quality Standards Regulation, or uses for which existing water quality is suitable unless prevented by physical problems such as substrate or flow.

Tier 2 – Protects the level of water quality necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water in waters that are currently of higher quality than required to support these uses. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economical or social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for non-point sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national resources, such as waters of national and state parks and wildlife refuges and water of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality (with the exception of some limited activities that result in temporary and short-term changes in water quality).

Specific Criteria:
The impairment of Lamar Lake is based on exceedence of the general criteria contained in Missouri's Water Quality Standards, 10 CSR 20-7.031 (3)(A) and (C). These criteria state:
- Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
- Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.

The impairment is also based on influencing the specific criteria at 10 CSR 20-7.031(4)(F) on Taste- and Odor-Producing Substances. There it says (in part):

> For those streams and lakes designated for drinking water supply use, the taste- and odor-producing substances shall be limited to concentrations that will not interfere with the production of potable water by reasonable water treatment processes.

Numeric Water Quality Target:
Excessive nutrients are causing the lake to be impaired, yet Missouri presently has no specific criteria for nutrients (phosphorus and nitrogen). Therefore, some number or level of nutrients must be derived that can be tied to the narrative criteria and can be used as the endpoint or target for Lamar Lake (see Reference Lake Approach below). When nutrient criteria becomes available, the Total Maximum Daily Load (TMDL) may be adjusted to reflect them.

Chlorophyll-a occurs in all green plants and is used as a measure of the amount of algae. When certain types of algae, blue-green algae, die, they release particular compounds that cause unpleasant taste and odor. Suspended chlorophyll-a has been found to predict the risk of dominance of blue-green algae. This risk increases exponentially when chlorophyll-a exceeds 10 µg/L[5] (MDNR, 2004). As already stated, Missouri does not have specific standards for nutrients. However, 27 µg/L total phosphorus was used for the McDaniel Lake TMDL as the concentration of phosphorus that would limit chlorophyll-a to 10 µg/L (MDNR, 2005). Appendices C-1 to C-3 summarize chlorophyll-a and total phosphorus data for Lamar Lake. Appendix D shows the linear regression between chlorophyll-a and total phosphorus for summer months (July – September). For comparison purpose, a scatter plot is presented using chlorophyll-a and total phosphorus data for all months, also in Appendix D.

<u>Reference Lake Approach</u>[6]

The "Reference Lake Approach" was used to derive the nutrient target in this TMDL. This approach compares two lakes, one attaining its uses and one impaired based on biological assessments. The objective of the process is to reduce the concentration of pollutants in the impaired lake to a level equivalent to that of the non-impaired, reference lake. The corresponding load reduction will result in conditions favorable to the return of a healthy biological community to the impaired lake.

In general, three factors are considered when selecting a suitable reference lake. The first factor is to use a lake that has been assessed and determined to be attaining water quality standards. The second factor is that the reference lake should be about 20 to 30 percent of the size of the watershed and the volume of the impaired lake. The third and last factor is to find a lake that closely resembles the impaired lake in hydrologic properties, such as land use or land cover, physiographic characteristics, and geology (U.S. EPA, 1998). Tables 1 and 2 illustrate the hydrologic characteristics and land use distributions of two candidate reference lakes relative to Lamar Lake. Data on these lakes are synthesized from research study of "Developing nutrient criteria for Missouri lakes" by Knowlton and Jones (2003).

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[5] µg/L = micrograms per liter. This is the same as parts per billion.
[6] This reference lake approach, the calculations in this section through section 7, and the graphs in Appendix D were created by Parsons Corporation, a Pasadena-based engineering and construction firm.

Table 1: Characteristics of Candidate Reference Lakes

Name	Latitude	Longtitude	Volume (ac-ft)	Area (ac)	Depth (m)	Distance from Impaired Lake (mi)
Lamar City	37.480000	-94.261667	1050	122.1	8.38	n/a
Harmony Mission	38.071660	-94.426940	935	96.7	4.12	41.50
Atkinson	38.006380	-94.046110	2722	480.8	5.26	38.00

Note: ac-ft = acre-feet; ac = acre; m = meters; mi = miles

Harmony Mission Lake is in south central Bates County, while Atkinson Lake is in southwest St. Clair County in the Schell-Osage Conservation Area. Part of it is in Vernon County. They are both Class L3 lakes, which includes all lakes that are not drinking water supplies or major reservoirs. They may be publicly or privately owned.

Table 2: Land Use Distribution of Candidate Reference Lakes

Lake Name		Land Use (acre)						Land Use Distribution (%)					
	Wateshed (ac)	Crops	Grassland	Wooded	Water	Urban	Barren	Crops	Grassland	Wooded	Water	Urban	Barren
Lamar Lake	**2962**	**677**	**1556**	**329**	**193**	**200**	**7**	23%	53%	11%	6.5%	6.8%	0.24%
Harmony Mission	1505	630	613	137	114	11	0	42%	41%	9%	7.6%	0.7%	0.00%
Atkinson	5029	1313	2138	1123	433	22	0	26%	43%	22%	8.6%	0.4%	0.00%

Based on land use, hydrologic and water quality data for these candidate reference lakes nearby (Tables 1 and 2), the closet matches for all above criteria for the Lamar Lake is Harmony Mission Lake.

Table 3: Established Total Phosphorus Target using Selected Reference Lake

Impaired Lake	Reference Lake	Chl-a (ug/L): 75% of reference lake data	Chl-a (ug/L): 25% of impaired and reference lake data	y	R2	P	a	b	x	TP target (ug/L)
Lamar Lake	Harmony Mission	27.19	19.24	1.2841	0.3446	0.00	0.966	-0.266	1.6047	40.24

log value equation: y =ax + b
x = log (targetted TP value)
y = log (lesser of Chl-a using 75% of reference lake data or 25% of all lake data)

Table 3 shows the regression analysis results using available data in summer months (July-September) from selected reference lake (Harmony Mission Lake). Based on these results, the TMDL endpoint is established as 40 µg/L Total Phosphorus (corresponding to 19 µg/L chlorophyll-a) in this TMDL study.

3. Load Capacity

Load Capacity (LC) is defined as the greatest amount of a pollutant (the load) a waterbody can assimilate without violating Missouri Water Quality Standards. This total load is then divided among a Wasteload Allocation (WLA) for point sources, a Load Allocation (LA) for non-point sources and a Margin of Safety (MOS) to account for uncertainties. As an equation, looks like this:

$$\mathbf{LC = WLA + LA + MOS} \qquad \text{(Eq. 1)}$$

To calculate the LC, the following steps were used:

(1) Estimate the mean residence time of the lake (Appendix E provides the details of the calculation steps)
    Result: 0.322 year, following methodology by Jones et. al (2004)
(2) Calculate the mean annual flow based on estimated residence time
    Result: 3,261-acre feet per year (acre-foot/year)
(3) Use the equation below with target Total Phosphorus concentration of 40 µg/L (from Table 3) and the above estimated flow:

*Load Capacity (as pounds per year) = Target Total Phosphorus Concentration (in µg/L) * Flow (in acre-foot / year) * 0.00272 (Conversion Factor)*
(Eq. 2)

LC = 40 * 3,261 * 0.00272 = 355 lbs./yr.

Therefore, the LC for Total Phosphorus in Lamar Lake is 355 lbs./yr.

4. Critical Conditions and Seasonal Variation

(1) Critical Condition for Low Flow/Dry Weather

The Clean Water Act [40 CFR 130.7(c)(1)] and U.S. EPA's TMDL regulations require that in developing TMDLs, one must "*take into account the critical conditions for stream flow, loading, and water quality parameters*". The "critical condition" is generally defined as the condition when the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or characteristic water uses. The intent of this requirement is to ensure that the water quality of the receiving waterbody is protected during times when it is most vulnerable.

The critical condition for this TMDL study is during summer low flow condition when the lake's volume is at its lowest and taste and odor events are most likely to occur. During the critical low flow period, impacts from wet weather sources are limited since storm runoff is minimal under dry weather conditions. Therefore, only data from the summer months (July-September) are used in the TMDL development.

(2) Considerations of Seasonal Variations

The TMDL target was derived using July-September data when taste and odor events in Lamar Lake were most likely to occur. By using data from this most problematic period instead of the entire year, the target is meant to prevent taste and odor occurrences year-round (MDNR, 2004).

If a phosphorus limit were instituted for the growing season only, it would ignore the effects of nutrient re-suspension in the water column within the lake. For this reason, it is recommended that the 40 µg/L Total Phosphorus and corresponding 19 µg/L chlorophyll-a target shall be in effect year-round.

5. Margin of Safety (MOS)

A MOS is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

(1) Explicit - Reserve a numeric portion of the loading capacity as a separate term in the TMDL.
(2) Implicit - Incorporate the MOS as part of the critical conditions for the WLA and the LA calculations by making conservative assumptions in the analysis.

Based on data availability for this TMDL study and guidance from EPA and MDNR, an explicit MOS of 10 percent of the LC capacity is reserved for the MOS.

6. Waste Load Allocation (WLA) (Point Source Loads)

The WLA is the maximum allowable amount of the pollutant that can be assigned to point sources. There are no point sources or Confined Animal Feeding Operations in the Lamar Lake watershed. Therefore, the WLA for this TMDL is set as zero pounds per day.

7. Load Allocation (LA) (Non-point Source Load)

LA is the maximum allowable amount of the pollutant that can be assigned to non-point sources. The LA can be calculated from (WQ. 1) by subtracting the WLA and MOS from the LC.

$$LC = WLA + LA + MOS \qquad \text{(Eq. 1)}$$

Rearranging the equation:

$$LA = LC – MOS – WLA \qquad \text{(Eq. 3)}$$

$$LA = 355 – 10\%*355 – 0 = 319 \text{ lbs./yr.}$$

Percentage of reduction required to meet calculated load capacity:
There are four sampling sites used in monitoring the nutrient levels in Lamar Lake. Appendix C-3 provides a table of Total Phosphorus data collected during summer months (July-September) from these sampling sites. The average Total Phosphorus concentration for Lamar Lake during these months from July 1989 through July 2005 is 102 µg/L.

Summary results of estimating required percentage of reduction is given as follow:

(1) *Current Total Phosphorus Loading (lbs//yr.) = Current Total Phosphorus Concentration (in µg/L) * Flow (in acre-foot / year) * 0.00272 (Conversion Factor)*
(Eq. 4)

Current Loading (lbs./yr.) = 102 * 3,261 * 0.00272

Current Loading = 905 lbs./yr.

(2) Determination of Required Load Reduction

% Total Phosphorus Reduction = (Existing Load – LA) / Existing Loading
(Eq. 5)
= (905 – 319) / 905 = 65%

Table 4 shows the distribution of existing pollutant load by land use. Table 5 summarizes the nutrient TMDL results for Lamar Lake.

Table 4: Distribution of Existing Pollutant Load by Land Use

Land Use	Crops	Grassland/Shrubs	Wooded/Forest	Urban	Water	Barren	Total
Land Use (Acre)	677	1556	329	200	193	7	2962
TP Loading Coefficient (lb/ac/yr)*	0.8	0.04	0.09	1.4	0	0	
TP Load (lb/yr)	535	62	28	280	0	0	905

*References:
(1) USEPA (1980). Modeling Phosphorus Loading and Lake Response under Uncertainty: A Manual and Compilation of Export Coefficients, EPA Report 440-5-80-011;
(2) U.S. Army Corps of Engineers (2004). Review of Published Export Coefficient and Event Mean Concentration (EMC) Data, Report ERDC TN-WRAP-04-3;
(3) Alexander, R. B., Smith, R. A., and Schwarz, G. E. (2004). Estimates of Diffuse Phosphorus Sources in Surface Wastes of the United States using a spatially referenced watershed model, *Water Sciences and Technology*, 49(3): 1-10; and (4) Haggard, B. E., Moore, P.A., Jr, Chaubey, I., Stanley, E. H. (2003). Nitrogen and Phosphorus Concentrations and Export from an Ozark Plateau Catchment in the United States, *Biosystems Engineering*, 86(1): 75-85

Table 5: Summary of Nutrient Results for Lamar Lake TMDL

TMDL (lbs./day)	**0.95**
LC (lbs./yr.)	**355**
WLA (lbs./yr.)	**0**
LA (lbs./yr.)	**319**
MOS (lbs./yr.)	**32**
Existing Load (lbs./yr.)	**905**
% Reduction	**65%**

8. Monitoring Plans for TMDL under the Phased Approach

Future monitoring of this lake involves both volunteers and department staff. In 2003, the Lakes of Missouri Volunteer Program (LMVP) started monitoring Lamar Lake. This program trains volunteers to collect high quality data from Missouri's lakes to monitor problems like excess nutrients. Volunteers collect data eight times a year from May-September. The parameters collected include Secchi depth, Total Phosphorus, total nitrogen, chlorophyll (total) and inorganic suspended solids. Monitoring will continue indefinitely on Lamar Lake as part of the LMVP. In addition, the department will schedule post-implementation monitoring beginning three years after implementation has been completed.

9. Implementation Plans

A Source Water Protection Plan (SWPP) for the Lamar Lake watershed was created in 2002 to protect the water sources (streams and wells) that feed Lamar's drinking water reservoir (Lamar Lake). The steering committee set up to create the original plan was reactivated. It is working with the Missouri Rural Water Association to review and update the plan. The group consists of stakeholders representing several of the different interests within the watershed. The objectives of this plan will serve as the implementation plan for the TMDL. These objectives include:

- Developing public and landowner awareness of non-point source pollution by conducting educational and informational activities.
- Improving water quality by reducing run-off of commercial chemicals and fertilizers, sediment and animal and human waste through the use of Best Management Practices in both urban and rural areas.

Natural Resource Conservation Service (NRCS) programs, in conjunction with the local soil and water conservation district, have accomplished much work to reduce runoff in the watershed.
A sampling of that work includes:

- Placing 71 acres in the Conservation Reserve Program (converting cropland to grassland);
- Placing 56 acres in the Conservation Reserve Enhancement Program;
- Assisting with installation and/or renovation of four grade stabilization structures in the last five years; and
- Converting approximately 300 acres from cropland to grassland (hay and pasture) through voluntary efforts of landowners with no cost share assistance in the last 10 years.

Also, according to an on-the-ground assessment by NRCS in February 2006, active cropland covers only about 200 acres, compared to 677 acres reported in the land use section. Additionally, there is a substantial buffer area between the lake and this cropland. Both of these factors provide added protection for the lake from storm water runoff.

This TMDL will be incorporated into Missouri's Water Quality Management Plan.

10. Reasonable Assurance

In most cases, "Reasonable Assurance" in reference to TMDLs relates only to point sources. As a result, any assurances that non-point source (NPS) contributors of nutrients will implement measures to reduce their contribution in the future will not be found in this section. Instead, discussion of reduction efforts relating to NPS can be found in the "Implementation" section of this TMDL.

11. Public Participation

On January 10, 2006, the Department of Natural Resources (the department) hosted a meeting in Lamar to inform the local citizenry about the need to update their SWPP. The department also discussed the upcoming TMDL, the local Wellhead Protection Plan and plans for watershed management in the greater Spring River Basin, starting with the upper north fork of that river.

At a second meeting on February 6, 2006, the group expressed interest in starting a watershed group for the upper north fork and formed a committee to go forward with updating the SWPP. Monthly meetings have been held since then, focusing on the SWPP and what stakeholders think can be done to reduce nutrients from entering Lamar Lake.

Lamar Lake is included on the approved 2002 303(d) list for Missouri. This TMDL was on public notice from May 19, 2006 to June 18, 2006. Groups who received the public notice announcement included the mailing list of those attending the Lamar Lake watershed meetings, Missouri Clean Water Commission, the Water Quality Coordinating Committee, seven Stream Team volunteers in the watershed and the two legislators representing Barton County. Also, the department posted the notice, the Lamar Lake Information Sheet and this document on its website, making them available to anyone with access to the Internet. The department has placed a copy of the notice, comments received and its responses to those comments in the Lamar Lake file, as detailed below.

12. Appendices and List of Documents on File with the Department

Appendix A – Land Use Types for the Lamar Lake Watershed
Appendix B – Location Map of Impaired Waterbody
Appendix C – Water Quality Data 1989-2005
Appendix D – Linear Regression graphs between chlorophyll-a and Total Phosphorus
Appendix E – TMDL Calculation

An administrative record on the Lamar Lake TMDL has been assembled and is being kept on file with the department. It includes the following:

- LMVP Reports for 2003, 2004 and 2005
- Phase I Diagnostic/Feasibility Study, Lamar Lake. 1993. (Clean Lakes of Missouri)
- TMDL for Lamar Lake, Barton County, Jan. 2006, Parsons Corporation
- Detailed modeling results
- Information Sheet

13. References

Alexander, R. B., Smith, R. A., and Schwarz, G. E. (2004). Estimates of Diffuse Phosphorus Sources in Surface Wastes of the United States using a spatially referenced watershed model, *Water Sciences and Technology*, 49(3): 1-10

Haggard, B. E., Moore, P.A., Jr, Chaubey, I., Stanley, E. H. (2003). Nitrogen and Phosphorus Concentrations and Export from an Ozark Plateau Catchment in the United States, *Biosystems Engineering*, 86(1): 75-85

Jones, J.R., Knowlton, M.F., Obrecht, D.V., and Cook, E.A. (2004) Importance of landscape variables and morphology on nutrients in Missouri reservoirs, *Can. J. Fish. Aquat. Sci.* 61: 1503-1512 (2004)

Knowlton, M. F, and Jones, J. R. (2003). Developing nutrient criteria for Missouri lakes, Report prepared by Department of Fisheries and Wildlife Sciences, University of Missouri, Columbia, MO

Missouri Department of Natural Resources (MDNR) (1986). Missouri Water Atlas, MDNR, Division of Geology and Land Survey, Rolla, MO

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Missouri Department of Natural Resources (MDNR) (2004). TMDL for McDaniel Lake, Greene County, Missouri. http://www.epa.gov/waters/tmdldocs/mcdaniel_lake_greenecty_finaltmdl.pdf

Missouri Department of Natural Resources (MDNR) (2004a). Quality Assurance Project Plan for Low Flow Surveys (State Fiscal Year 2004)

Missouri Department of Natural Resources (MDNR) (2005). TMDL Information Sheet – Lamar Lake, http://www.dnr.mo.gov/env/wpp/tmdl/info/lamar-lk-info.pdf

U. S. Department of Agriculture (USDA) (2005). National Handbook of Conservation Practices (NHCP), http://www.nrcs.usda.gov/technical/standards/nhcp.html

USEPA (1980). Modeling Phosphorus Loading and Lake Response under Uncertainty: A Manual and Compilation of Export Coefficients, EPA Report 440-5-80-011

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USEPA (1999). Protocol for Developing Nutrient TMDLs (First Edition), EPA Report 841-B-99-007

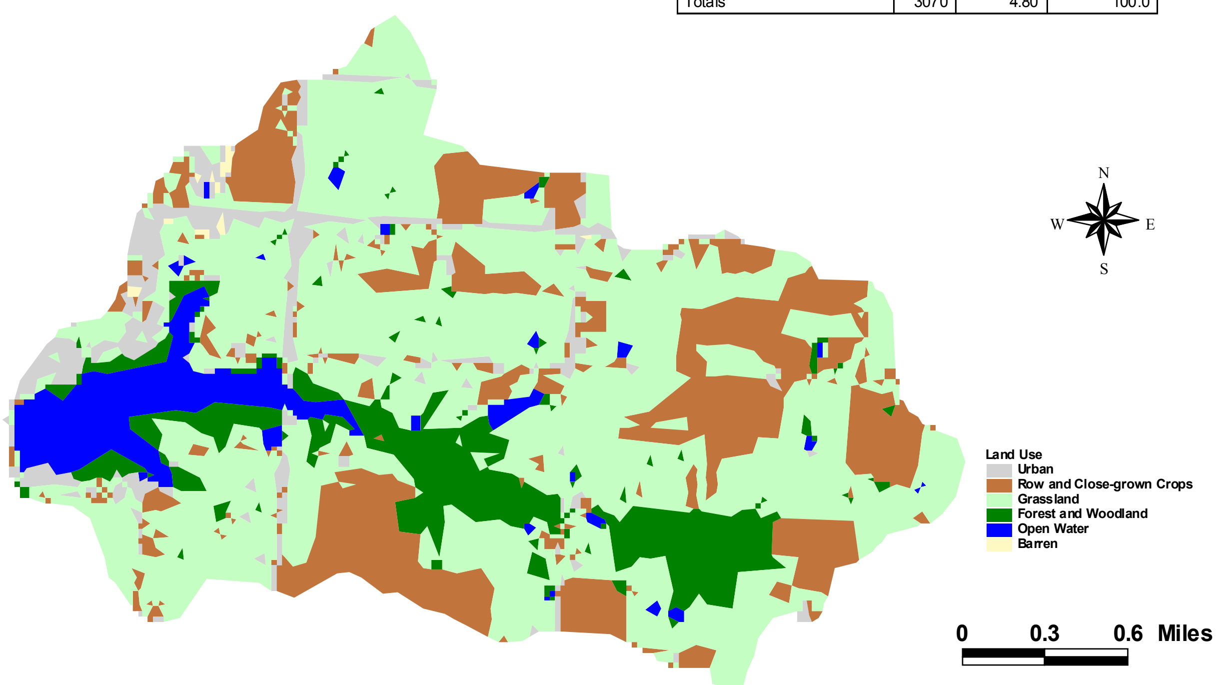
USEPA (1999a). Draft Guidance for Water Quality-based Decisions: The TMDL Process (Second Edition), EPA Report 841-D-99-001

USEPA (2000). Ambient Water Quality Criteria Recommendations: Lakes and Reservoirs in Nutrient Ecoregion XI, EPA Report 822-B-00-012

U.S. Army Corps of Engineers (2004). Review of Published Export Coefficient and Event Mean Concentration (EMC) Data, Report ERDC TN-WRAP-04-3

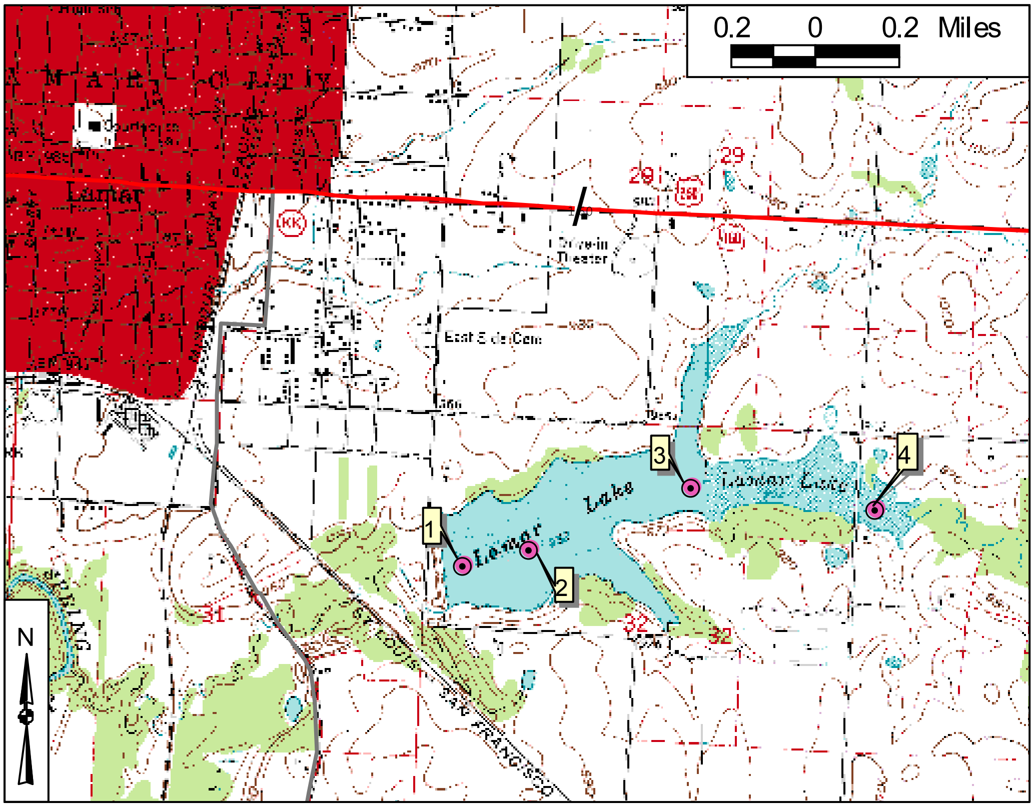
Appendix A
Land Use Types for Lamar Lake (11070207-070001)

Land Use Type	Acres	Sq. Miles	Percentage
Urban	208	0.33	6.8
Row and Close-grown Crops	690	1.08	22.5
Grassland	1642	2.57	53.5
Forest and Woodland	329	0.51	10.7
Open Water	193	0.30	6.3
Barren	7	0.01	0.2
Totals	3070	4.80	100.0



Data source: 2000 data (30 meter resolution) obtained from Thematic Mapper imagery was used to calculate these land use statistics. These figures differ slightly from the land use figures (Knowlton and Jones, 2003) used in the TMDL calculations.

Appendix B
Lamar Lake with Sample Sites in Barton County, Missouri



Site Index
1 – Lamar City Lake bear dam
2 – Lamar City Lake main body
3 – Lamar City Lake east arm
4 – Lamar City Lake near upper end

Appendix C
Water Quality Data for Lamar Lake

C-1. Water Quality Data (TP and Chl-a) for All Months at Site #1
July 1989 – July 1996

Date	Sampling Site	Total Phosphorous (µg/L)	Chlorophyll-a (µg/L)	log10 TP	log10 Chl-a
13-Jun-89	1: Near Dam	65.00	32.40	1.8129	1.5105
13-Jun-89	1: Near Dam	65.00	34.20	1.8129	1.5340
17-Jul-89	1: Near Dam	65.00	32.00	1.8129	1.5051
17-Jul-89	1: Near Dam	74.00	40.30	1.8692	1.6053
21-Aug-89	1: Near Dam	64.00	21.40	1.8062	1.3304
21-Aug-89	1: Near Dam	63.00	22.00	1.7993	1.3424
4-Jun-90	1: Near Dam	148.00	117.10	2.1703	2.0686
4-Jun-90	1: Near Dam	149.00	124.60	2.1732	2.0955
10-Jul-90	1: Near Dam	71.00	34.60	1.8513	1.5391
10-Jul-90	1: Near Dam	76.00	35.10	1.8808	1.5453
7-Aug-90	1: Near Dam	101.00	45.50	2.0043	1.6580
7-Aug-90	1: Near Dam	113.00	50.00	2.0531	1.6990
11-Jun-91	1: Near Dam	34.00	30.60	1.5315	1.4857
11-Jun-91	1: Near Dam	50.00	39.70	1.6990	1.5988
9-Jul-91	1: Near Dam	60.00	41.40	1.7782	1.6170
9-Jul-91	1: Near Dam	61.00	43.70	1.7853	1.6405
6-Aug-91	1: Near Dam	62.00	26.60	1.7924	1.4249
6-Aug-91	1: Near Dam	73.00	30.20	1.8633	1.4800
16-Jun-92	1: Near Dam	59.00	43.00	1.7709	1.6335
16-Jun-92	1: Near Dam	60.00	46.60	1.7782	1.6684
14-Jul-92	1: Near Dam	142.00	45.20	2.1523	1.6551
14-Jul-92	1: Near Dam	150.00	48.20	2.1761	1.6830
10-Aug-92	1: Near Dam	94.00	71.70	1.9731	1.8555
10-Aug-92	1: Near Dam	99.00	76.10	1.9956	1.8814
15-Jun-93	1: Near Dam	72.00	44.20	1.8573	1.6454
15-Jun-93	1: Near Dam	70.00	50.60	1.8451	1.7042
12-Jul-93	1: Near Dam	73.00	41.90	1.8633	1.6222
12-Jul-93	1: Near Dam	71.00	46.20	1.8513	1.6646
9-Aug-93	1: Near Dam	59.00	37.80	1.7709	1.5775
9-Aug-93	1: Near Dam	69.00	42.60	1.8388	1.6294
22-Feb-94	1: Near Dam	43.00	19.70	1.6335	1.2945
22-Feb-94	1: Near Dam	44.00	20.20	1.6435	1.3054
15-Mar-94	1: Near Dam	60.00	21.80	1.7782	1.3385
15-Mar-94	1: Near Dam	48.00	22.20	1.6812	1.3464
5-Apr-94	1: Near Dam	44.00	15.80	1.6435	1.1987
5-Apr-94	1: Near Dam	46.00	17.80	1.6628	1.2504
26-Apr-94	1: Near Dam	119.00	33.20	2.0755	1.5211
26-Apr-94	1: Near Dam	142.00	33.80	2.1523	1.5289
16-May-94	1: Near Dam	70.00	20.10	1.8451	1.3032
16-May-94	1: Near Dam	70.00	20.60	1.8451	1.3139

13-Jun-94	1: Near Dam	68.00	39.70	1.8325	1.5988
13-Jun-94	1: Near Dam	108.00	59.20	2.0334	1.7723
11-Jul-94	1: Near Dam	74.00	27.60	1.8692	1.4409
11-Jul-94	1: Near Dam	75.00	28.80	1.8751	1.4594
9-Aug-94	1: Near Dam	43.00	16.10	1.6335	1.2068
9-Aug-94	1: Near Dam	48.00	30.70	1.6812	1.4871
30-Aug-94	1: Near Dam	49.00	33.00	1.6902	1.5185
30-Aug-94	1: Near Dam	81.00	79.00	1.9085	1.8976
20-Sep-94	1: Near Dam	44.00	22.20	1.6435	1.3464
20-Sep-94	1: Near Dam	47.00	26.60	1.6721	1.4249
11-Oct-94	1: Near Dam	46.00	26.70	1.6628	1.4265
11-Oct-94	1: Near Dam	44.00	27.80	1.6435	1.4440
1-Nov-94	1: Near Dam	37.00	25.20	1.5682	1.4014
1-Nov-94	1: Near Dam	36.00	26.10	1.5563	1.4166
6-Dec-94	1: Near Dam	82.00	20.50	1.9138	1.3118
6-Dec-94	1: Near Dam	84.00	21.80	1.9243	1.3385
31-May-95	1: Near Dam	96.00	41.40	1.9823	1.6170
31-May-95	1: Near Dam	100.00	41.60	2.0000	1.6191
27-Jun-95	1: Near Dam	102.00	22.60	2.0086	1.3541
27-Jun-95	1: Near Dam	102.00	22.70	2.0086	1.3560
1-Aug-95	1: Near Dam	79.00	41.70	1.8976	1.6201
1-Aug-95	1: Near Dam	82.00	44.40	1.9138	1.6474
29-May-96	1: Near Dam	59.00	30.60	1.7709	1.4857
29-May-96	1: Near Dam	56.00	31.10	1.7482	1.4928
25-Jun-96	1: Near Dam	62.00	36.10	1.7924	1.5575
25-Jun-96	1: Near Dam	70.00	38.90	1.8451	1.5899
30-Jul-96	1: Near Dam	69.00	47.70	1.8388	1.6785
30-Jul-96	1: Near Dam	70.00	50.20	1.8451	1.7007
Mean		73.69	37.95	1.8395	1.5369

Note: The University of Missouri in Columbia (Dr. Jones) collected all lake data. Chlorophyll–a parameter was replaced with Total Chlorophyll after 1996.

C-2. Water Quality Data (TP and Chl-a) for Summer Months (July – September) at Site #1 July 1989 – July 1996

Date	Sampling Site	Total Phosphorous (µg/L)	Chlorophyll-a (µg/L)	log10 TP	log10 Chl-a
17-Jul-89	1: Near Dam	65.00	32.00	1.8129	1.5051
17-Jul-89	1: Near Dam	74.00	40.30	1.8692	1.6053
21-Aug-89	1: Near Dam	64.00	21.40	1.8062	1.3304
21-Aug-89	1: Near Dam	63.00	22.00	1.7993	1.3424
10-Jul-90	1: Near Dam	71.00	34.60	1.8513	1.5391
10-Jul-90	1: Near Dam	76.00	35.10	1.8808	1.5453
7-Aug-90	1: Near Dam	101.00	45.50	2.0043	1.6580
7-Aug-90	1: Near Dam	113.00	50.00	2.0531	1.6990
9-Jul-91	1: Near Dam	60.00	41.40	1.7782	1.6170
9-Jul-91	1: Near Dam	61.00	43.70	1.7853	1.6405
6-Aug-91	1: Near Dam	62.00	26.60	1.7924	1.4249
6-Aug-91	1: Near Dam	73.00	30.20	1.8633	1.4800

14-Jul-92	1: Near Dam	142.00	45.20	2.1523	1.6551
14-Jul-92	1: Near Dam	150.00	48.20	2.1761	1.6830
10-Aug-92	1: Near Dam	94.00	71.70	1.9731	1.8555
10-Aug-92	1: Near Dam	99.00	76.10	1.9956	1.8814
12-Jul-93	1: Near Dam	73.00	41.90	1.8633	1.6222
12-Jul-93	1: Near Dam	71.00	46.20	1.8513	1.6646
9-Aug-93	1: Near Dam	59.00	37.80	1.7709	1.5775
9-Aug-93	1: Near Dam	69.00	42.60	1.8388	1.6294
11-Jul-94	1: Near Dam	74.00	27.60	1.8692	1.4409
11-Jul-94	1: Near Dam	75.00	28.80	1.8751	1.4594
9-Aug-94	1: Near Dam	43.00	16.10	1.6335	1.2068
9-Aug-94	1: Near Dam	48.00	30.70	1.6812	1.4871
30-Aug-94	1: Near Dam	49.00	33.00	1.6902	1.5185
30-Aug-94	1: Near Dam	81.00	79.00	1.9085	1.8976
20-Sep-94	1: Near Dam	44.00	22.20	1.6435	1.3464
20-Sep-94	1: Near Dam	47.00	26.60	1.6721	1.4249
1-Aug-95	1: Near Dam	79.00	41.70	1.8976	1.6201
1-Aug-95	1: Near Dam	82.00	44.40	1.9138	1.6474
30-Jul-96	1: Near Dam	69.00	47.70	1.8388	1.6785
30-Jul-96	1: Near Dam	70.00	50.20	1.8451	1.7007
Mean		75.03	40.02	1.8558	1.5745

C-3. Total Phosphorus Data for Summer Months (July – September) July 1989 – July 2005, at Sites #1- 4

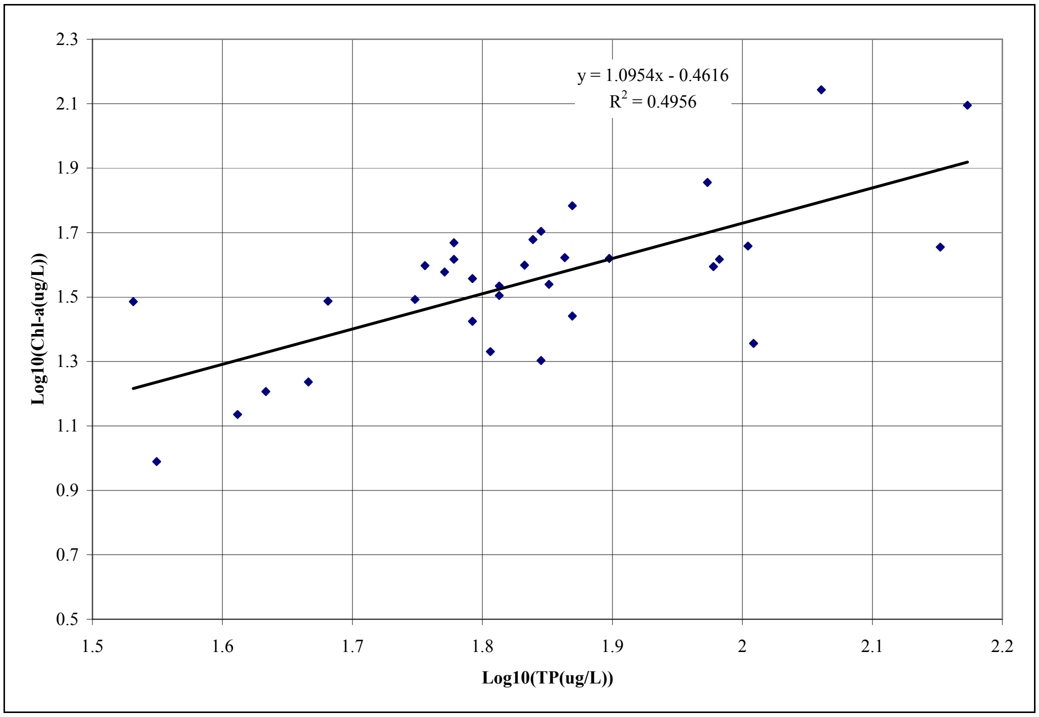
Date	Sampling Site	Total Phosphorous (µg/L)	log10 TP
17-Jul-89	Near Dam	65.00	1.8129
17-Jul-89	Near Dam	74.00	1.8692
21-Aug-89	Near Dam	64.00	1.8062
21-Aug-89	Near Dam	63.00	1.7993
10-Jul-90	Near Dam	71.00	1.8513
10-Jul-90	Near Dam	76.00	1.8808
7-Aug-90	Near Dam	101.00	2.0043
7-Aug-90	Near Dam	113.00	2.0531
9-Jul-91	Near Dam	60.00	1.7782
9-Jul-91	Near Dam	61.00	1.7853
6-Aug-91	Near Dam	62.00	1.7924
6-Aug-91	Near Dam	73.00	1.8633
14-Jul-92	Near Dam	142.00	2.1523
14-Jul-92	Near Dam	150.00	2.1761
17-Jul-92	Main Body	150.00	2.1761
17-Jul-92	Main Body	170.00	2.2304
17-Jul-92	Main Body	180.00	2.2553
17-Jul-92	East Arm	200.00	2.3010
17-Jul-92	East Arm	240.00	2.3802
17-Jul-92	East Arm	450.00	2.6532

3-Aug-92	Main Body	80.00	1.9031
3-Aug-92	Main Body	230.00	2.3617
3-Aug-92	Main Body	200.00	2.3010
3-Aug-92	East Arm	90.00	1.9542
3-Aug-92	East Arm	90.00	1.9542
10-Aug-92	Near Dam	94.00	1.9731
10-Aug-92	Near Dam	99.00	1.9956
12-Aug-92	Main Body	60.00	1.7782
12-Aug-92	Main Body	70.00	1.8451
12-Aug-92	Main Body	190.00	2.2788
12-Aug-92	East Arm	70.00	1.8451
12-Aug-92	East Arm	80.00	1.9031
12-Aug-92	East Arm	440.00	2.6435
28-Aug-92	Main Body	80.00	1.9031
28-Aug-92	Main Body	50.00	1.6990
28-Aug-92	Main Body	60.00	1.7782
28-Aug-92	East Arm	160.00	2.2041
28-Aug-92	East Arm	90.00	1.9542
28-Aug-92	East Arm	250.00	2.3979
14-Sep-92	Main Body	50.00	1.6990
14-Sep-92	Main Body	60.00	1.7782
14-Sep-92	Main Body	70.00	1.8451
12-Jul-93	Near Dam	73.00	1.8633
12-Jul-93	Near Dam	71.00	1.8513
9-Aug-93	Near Dam	59.00	1.7709
9-Aug-93	Near Dam	69.00	1.8388
11-Jul-94	Near Dam	74.00	1.8692
11-Jul-94	Near Dam	75.00	1.8751
9-Aug-94	Near Dam	43.00	1.6335
9-Aug-94	Near Dam	48.00	1.6812
30-Aug-94	Near Dam	49.00	1.6902
30-Aug-94	Near Dam	81.00	1.9085
20-Sep-94	Near Dam	44.00	1.6435
20-Sep-94	Near Dam	47.00	1.6721
1-Aug-95	Near Dam	79.00	1.8976
1-Aug-95	Near Dam	82.00	1.9138
30-Jul-96	Near Dam	69.00	1.8388
30-Jul-96	Near Dam	70.00	1.8451
21-Jul-03	Near Dam	97.00	1.9868
21-Jul-03	Near Upper End	76.00	1.8808
11-Aug-03	Near Dam	75.00	1.8751
11-Aug-03	Near Upper End	72.00	1.8573
29-Aug-03	Near Dam	71.00	1.8513
29-Aug-03	Near Upper End	95.00	1.9777
15-Sep-03	Near Dam	59.00	1.7709
15-Sep-03	Near Upper End	71.00	1.8513
29-Sep-03	Near Dam	63.00	1.7993
29-Sep-03	Near Upper End	58.00	1.7634

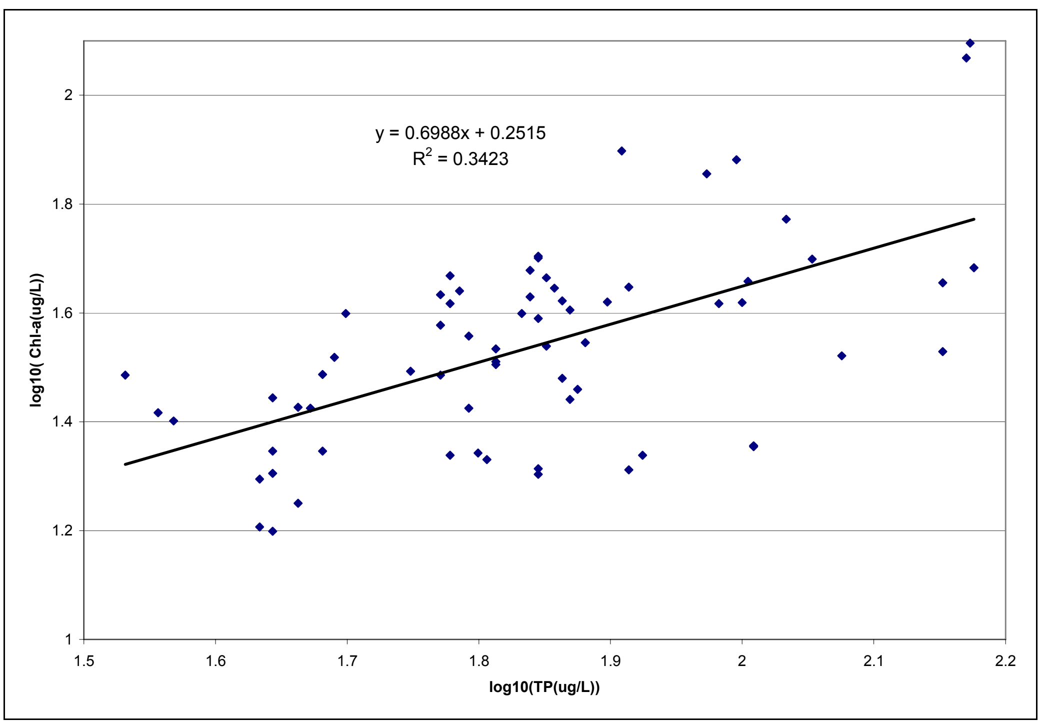
12-Jul-04	Near Dam	86.00	1.9345
12-Jul-04	Near Upper End	149.00	2.1732
2-Aug-04	Near Dam	90.00	1.9542
2-Aug-04	Near Upper End	114.00	2.0569
23-Aug-04	Near Dam	84.00	1.9243
23-Aug-04	Near Upper End	90.00	1.9542
13-Sep-04	Near Dam	66.00	1.8195
13-Sep-04	Near Upper End	74.00	1.8692
8-Jul-05	Near Dam	87.00	1.9395
8-Jul-05	Near Dam	81.00	1.9085
MEAN		101.53	1.9430

Appendix D

Linear Regression between Chlorophyll-a and Total Phosphorus Summer Months (July – September) 1989-1996



Linear Regression between Chlorophyll-a and Total Phosphorus All Data (1989-1996)



Appendix E
TMDL Calculation

The steps and values used in calculating the TMDL for Total Phosphorus are as follows:

(1) Average total phosphorus concentration for Lamar City Lake during summer months (July – September) is 102 µg/L.

(2) Estimate mean residence time of the lake (Jones et. al, 2004):

Mean Residence Time = Lake Volume / Lake Inflow
Where,

Lake Volume = (1/4 Dam Height) * Lake Surface Area
Lake Inflow = Lake Watershed Area * Runoff (from Missouri Water Atlas)
Lamar Lake Surface Area = 122.1 acres; Lake Watershed Area = 2,962 acres

The residence time for Lamar Lake is estimated as 0.322 year (3.9 month). Please refer to the following table:

Residence Time Calculation	Dam Height (ft)	Lake Area (ac)	Volume (ac-ft)	Watershed (ac)	Runoff (inch)	Lake Inflow (ac-ft)	Residence Time (year)
Lamar Lake	26	122.1	794	2962	10	2468	0.322

References:
(a) Jones, J.R., Knowlton, M.F., Obrecht, D.V., and Cook, E.A. (2004) Importance of landscape variables and morphology on nutrients in Missouri reservoirs, *Can. J. Fish. Aquat. Sci.* 61: 1503-1512 (2004)
(b) Missouri Department of Natural Resources (MDNR) (1986). Missouri Water Atlas, MDNR, Division of Geology and Land Survey, Rolla, MO

(3) Calculate mean annual flow based on estimated residence time:
Estimated mean annual flow for Lamar Lake using the lake volume from Table 1 page 5
= 1050 ac-ft / 0.322 year = 3,261 ac-ft/yr

(4) Calculation of Target TP Loading:
Use equation below with target TP concentration of 40 µg/L (from Table 4) and the above estimated flow:
*Target TP Loading (lb/yr) = Target TP Concentration (in µg/L) * Flow (in ac-ft/yr) * 0.00272 (Conversion Factor)*

Target Loading (lb/yr) = 40 * 3,261 * 0.00272

Target Loading (Loading Capacity) = 355 lb/yr

TMDL = 355 lb/yr divided by 356 days/yr = 0.97 pounds per day

(5) Calculation of Current TP Loading:
Use equation below with current TP concentration of 102 µg/L and the above estimated flow:
*Current TP Loading (lb/yr) = Current TP Concentration (in µg/L) * Flow (in ac-ft/yr) * 0.00272 (Conversion Factor)*

Current Loading (lb/yr) = 102 * 3,261 * 0.00272

Current Loading = 905 lb/yr